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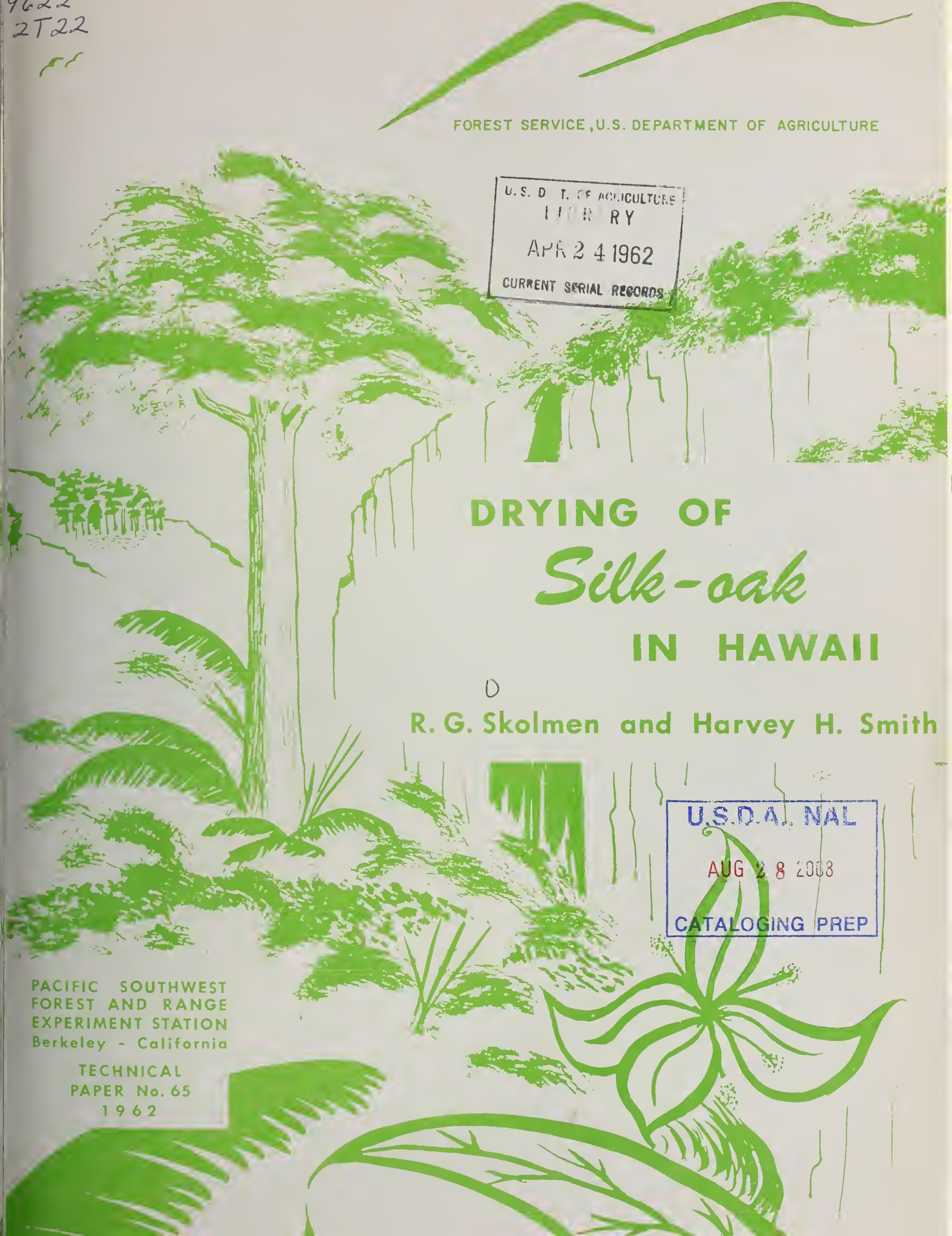

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DRYING OF *Silk-oak* IN HAWAII

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R. G. Skolmen and Harvey H. Smith

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SUMMARY

The lumber industry in Hawaii needs information on methods of lumber drying suited to local climatic conditions. A study of methods of piling silk-oak in Hilo, Hawaii, showed that 5-foot spacing between piles caused more rapid drying with less degrade than 1-foot spacing. Roofing had no influence on drying rate or degrade. Lumber in the bottom part of each pile did not dry as much as that higher up. Main causes of degrade were blue stain of sapwood (8.9 percent), end splitting (6.7 percent), and surface checking (5.6 percent). Warp was an insignificant cause of degrade (0.3 percent).

The findings indicate that wide spacing of piles is desirable for wet areas in Hawaii. A chemical dip to control blue stain and beetle damage, and protection of the ends of the piles to reduce end splitting, appear desirable, along with better yard drainage, including paving, to promote more rapid drying.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the assistance of M. L. Wold, manager of Hawaiian Fern-Wood, Ltd., who provided lumber and facilities for this research, and of G. D. Pickford of the Hawaii Division of Forestry, who recorded most of the data during the air drying.

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By
R. G. 20 Skolmen and Harvey H. Smith

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7a PACIFIC SOUTHWEST FOREST AND RANGE EXPERIMENT STATION
5a BERKELEY, CALIF~~ORNIA~~

DRYING OF SILK-OAK IN HAWAII

By
Roger G. Skolmen[1] and Harvey H. Smith[2]

Silk-oak (Grevillea robusta A. Cunn.) has been planted extensively in Hawaii. Some stands have now reached sawtimber size and are being logged and manufactured into lumber. In past years silk-oak was exported from its native Australia as lacewood. It was considered an excellent cabinet wood suitable for furniture, paneling, flooring, and similar high-value end uses. Hawaii-grown silk-oak is almost identical in appearance to another wood presently exported from Australia, Cardwellia sublimis, also known as lacewood.

To date little is known about the drying of lumber milled from trees grown in Hawaii. The study reported here was undertaken to answer some of the questions about the drying of silk-oak. Though this initial study was concerned primarily with air drying, the study material was kiln-dried to a low final moisture content suitable for cabinet wood.

Air drying of lumber is influenced greatly by weather conditions and the methods of piling lumber on the yard. Hawaii has a great climatic variation from one location to another. In some inhabited areas rainfall exceeds 150 inches annually and high humidity prevails; here, very mild drying conditions often result in such slow drying of lumber that stain and mold develop. Other areas have less than 20 inches annual rainfall and low humidity; here, drying conditions are severe and end splitting and surface checking may develop during drying. Since weather conditions vary greatly within relatively short distances, an area best suited for the air drying of local woods might be selected when planning installation of a sawmill. At a given location the effects of adverse weather can be minimized; drying conditions can be controlled on the air-drying yard by the methods of piling and protecting the piles of lumber from direct sun and rain.

PROCEDURE

This experiment was designed to study methods of yard piling and pile protection for the effective control of air-drying conditions to promote rapid drying without objectionable degrade. Records of the prevailing weather conditions at the study area in Hilo, Hawaii, were obtained so that results could be applied with some degree of accuracy in other areas of Hawaii.

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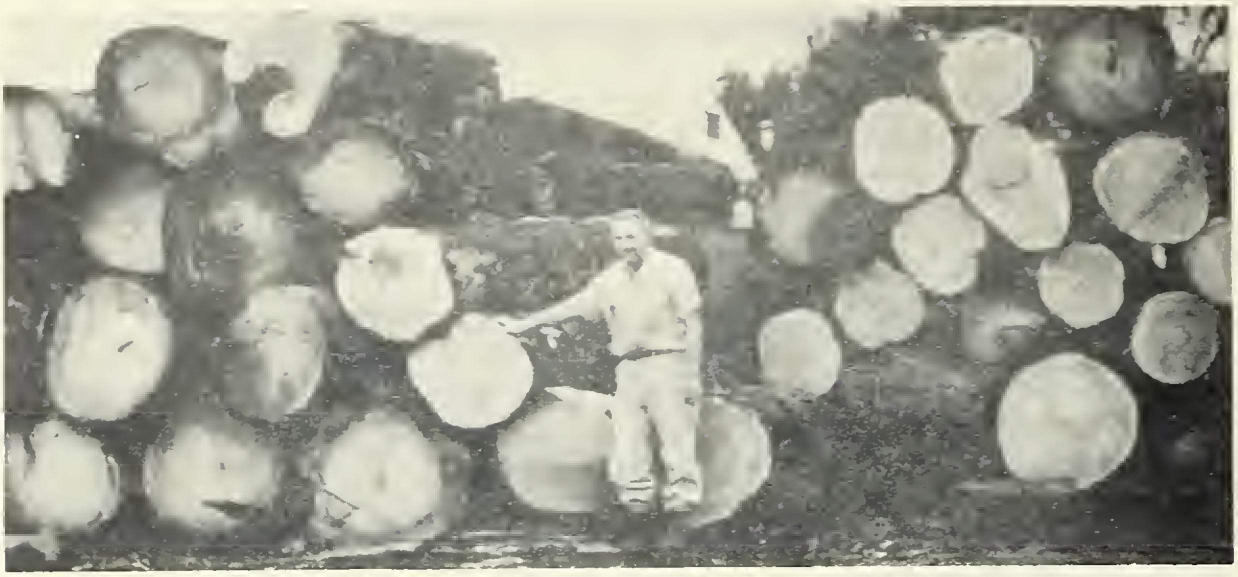

Figure 1.--Hawaiian-grown silk-oak logs at the sawmill, Hilo.

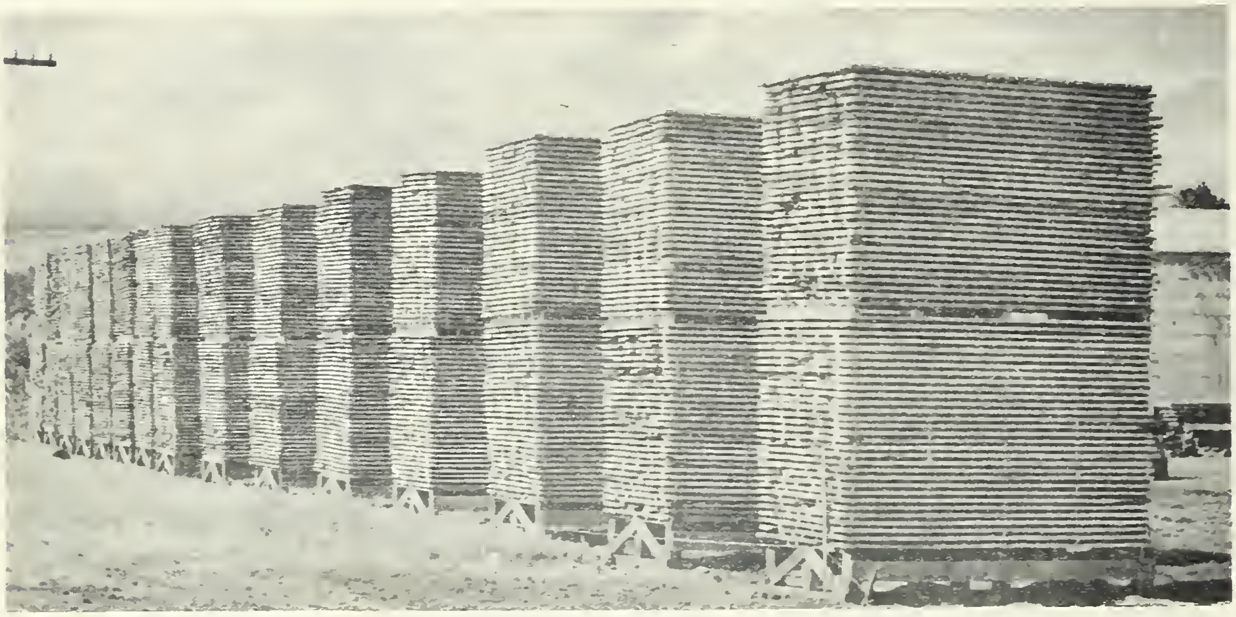

Figure 2.--Air-drying piles spaced 1 foot and 5 feet on pile foundations $15\frac{1}{2}$ inches high above the ground.

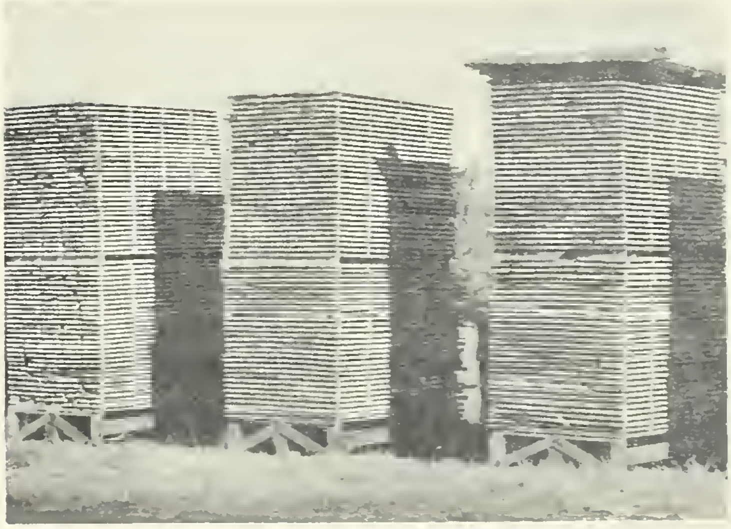

Figure 3.--Metal roofing on study pile number 6 at 5-foot spacing. Similar roofs were placed on pile 7 and on piles 2 and 3 at 1-foot spacing.

Two variables of piling--pile spacing and pile roofing--were studied to measure their effect on rate of drying and the occurrence of drying defects. One-inch by 6-, 8-, 10-, and 12-inch boards were sawed from 8-foot logs at the sawmill of Hawaiian Fern-Wood, Ltd. (fig. 1). These boards were piled into nominal 4- x 4- x 8-foot packages, 15 courses high, using 5 stickers per course. The packages were piled 2 high on firm, level foundations that raised the bottom package 15½ inches above the ground (fig. 2).

Two replications of each treatment were provided by using 8 piles of study lumber, 4 spaced at 1 foot and 4 spaced at 5 feet. Piles 2 and 3 at 1-foot spacing and 6 and 7 at 5-foot spacing were roofed with corrugated sheet iron (fig. 3). Isolation piles of non-study lumber were placed at the ends of the row and between piles of study lumber at the two spacings.

The rough-green lumber consisted of boards estimated by mill workers to be Firsts, Seconds, and Selects in grade. The topmost course on each pile was of lower grade lumber.

Sixteen sample boards were prepared for measuring the progress of the drying. Two samples were inserted in the space between the top and bottom package in each pile. Special 3-inch-thick bolsters were used to give the samples the same spacing as lumber elsewhere in the pile. Pieces of lumber similar in size to the samples were placed on either side of the 2 samples in each of the 8 piles of study lumber. Samples were not exposed at the edges of the piles, and the indicated drying rates should represent average or somewhat slower than average values. The sample boards were weighed to the nearest half ounce each week or once every 2 weeks until the lumber approached its equilibrium moisture content, and less often thereafter.

A sample of lumber was removed from the piles at the completion of air drying for an evaluation of moisture content, surface and end checking, and change in grade during drying. The sample consisted of 488 boards containing 2,843 board feet, or 20 percent of the lumber in the 8 study piles. The boards were taken in equal amounts from 3 positions (top, middle, and bottom 4 courses) in each pile. The topmost course of each pile was of low grade lumber and was not included in the sample.

The 20-percent sample was made up into four 4- x 4-foot packages. After a month of open storage on the yard, these packages were kiln-dried at 125°F. in a forced-air drier. After kiln drying, the lumber was surfaced and re-evaluated. Moisture content readings were made with an electrical moisture meter at 3 points across the face of each board. The lumber was graded according to the standard rules of the National Hardwood Association. Minute knots and blemishes which are peculiarities of silk-oak[3] were considered defects though they would probably be excluded in a standard rule designed for this wood. The lumber was graded as Firsts, Seconds, Selects, and Nos. 1, 2, 3A, and 3B Common.

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[3] Malcolm, F. B. Quality evaluation of Hawaiian timber. U.S. Forest Serv. Forest Products Laboratory Report No. 2226. 13 pp. tables, illus. 1961.

RESULTS

RATE OF DRYING

The lumber was dried for 139 days, from December 13, 1960 to May 1, 1961. Throughout the first 57 days of the experiment, when most of the drying occurred, unusually dry weather prevailed in Hilo (fig. 4). The dry spell was followed by an extremely wet month, typical of Hilo at that time of year. This rainy period with its resultant high humidity greatly reduced the drying rate. The wet period was followed by normal Hilo weather for the rest of the drying period, and the lumber gradually dried to near its equilibrium moisture content of 14 to 16 percent.

Silk-oak is exceptionally wet as it comes from the saw. The beginning moisture content of 125 to 130 percent in this study is probably normal for the species. Despite this high moisture content, all piles dried rapidly in the early stages of drying.

Piles at 5-foot spacing dried significantly faster. They frequently were 15 to 18 days ahead of 1-foot spaced piles; at one point 37 days ahead. They dried to a moisture content of 22 percent one month before the 1-foot spaced piles. Covering the piles appeared to have little influence on the rate of drying, at least in the central part of the piles where the moisture samples were located.

Although Hilo lies in the northeast trade wind belt, the wind that prevailed most frequently during drying was from the southwest quadrant (table 1) because of cold air drainage from nearby high mountains during the night and early morning. Winds from other directions, principally northeast trade winds in late morning and afternoon hours, were much less frequent, but often of somewhat higher velocity. The row of lumber piles was positioned in an east-west direction with full exposure on the south to take advantage of the prevailing southwest winds. If the winds during the study period were normal, it would seem desirable to use a similar orientation of the rows of piles when expanding this yard or laying out a new yard in this general area.

In an area of high rainfall and humidity such as Hilo, an "open" yard helps utilize the prevailing winds to dry the yard after rains. Other important factors to consider in promoting rapid lumber drying are good surface drainage; control of weeds and other vegetation that retard air movement; high, open pile foundations; and narrow piles.

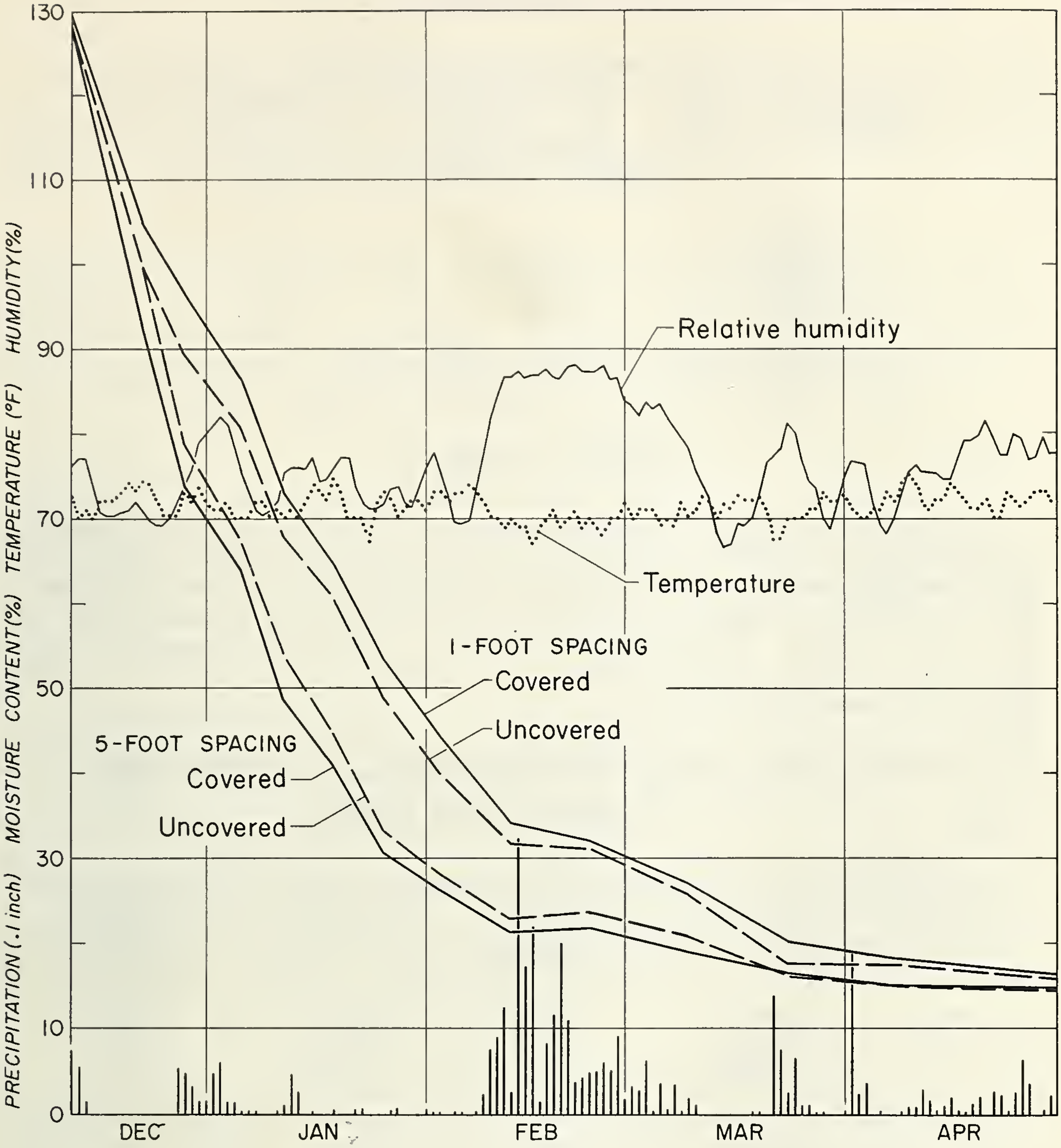

Figure 4.--Drying rates of samples with average temperatures, relative humidity (running 5-day average), and precipitation.

Table 1.--Wind during the air-drying period[1]

Wind direction, quadrant	Prevailing wind during drying days	Average velocity
	Number of days	m.p.h.
N to ENE	16	9.8
E to SSE	8	10.1
S to WSW	104	9.0
W to NNW	11	9.0

[1] Data from Hilo office, U.S. Weather Bureau, one-fourth mile from the drying yard at the same elevation.

MOISTURE CONTENT

There was little or no difference in moisture content of sample boards from roofed and unroofed piles, but consistent differences between pile spacings and by vertical position in the pile. Lumber piled at 5-foot spacing was almost 2 percent lower in moisture content than that at 1-foot spacing. The moisture content of the bottom courses of all piles was about 2 percent higher than the moisture content of the middle and top courses (table 2).

Table 2.--Electrical moisture meter readings[1], 20-percent sample of air-dried lumber

Spacing	Protection	Moisture content	Position	Moisture content
		Percent		Percent
One foot	Open	24.3	Top	23.0
	Roofed	24.5	Middle	23.9
	Average	24.4	Bottom	26.4
Five feet	Open	23.0	Top	21.9
	Roofed	22.3	Middle	21.8
	Average	22.6	Bottom	24.2

[1] Comparative values only—correction factor for Hawaii-grown silk-oak not available.

Kiln drying was merely a finishing off process in this study, done to dry the lumber down to 8 to 10 percent for use in Honolulu. The equilibrium moisture content at Honolulu, which has a dryer climate than Hilo, is about 11 to 12 percent.

DEGRADE

The principal defects caused by drying that resulted in the lowering of grade were, in descending order of severity, blue stain of sapwood, end splitting, and surface checking. Warp, in any form, caused very little degrade. Though many boards exhibited slight crook, this crook was never sufficient to reduce the grade.

Almost all sapwood stained in all piles, whether at wide or narrow spacing, covered or uncovered. Heartwood did not stain except on the underside of the bottom course of each pile. These courses rested on the foundations and came into contact with iron nailheads. The nails produced rust spots on the rough lumber surface. These appeared as deep bluish spots on the surfaced lumber.

An analysis of the drying defect figures (linear inches of all visible surface checks and of end checks and splits on the 20-percent sample) showed no significant differences between the close and wide pile spacings, between the roofed and unroofed piles, or between top, middle, and bottom position in the pile. These visible drying defects (checks, splits, warp, etc.) may or may not result in a change of grade. Many of the small, shallow surface checks and limited end splits did not affect the grade.

An analysis of the loss of grade by number of pieces and board footage from green to air-dried condition showed a significant difference between the 1-foot and the 5-foot spacing, there being almost twice as much degrade due to end splits, surface checks, and warp in the closer spacing (table 3). Stain, on the other hand was about the same, there being only slightly greater loss of grade in lumber from the piles at the closer spacing. Since almost all sapwood stained, any variation in amount of stain was the result of variation in the amount of sapwood in the piles--not variation in the piling methods. There was no significant difference in degrade occurring at different vertical positions in the pile or in roofed and unroofed piles.

Of the four causes of degrade during air drying, stain accounted for the greatest loss--8.9 percent compared to 8.0 percent for the other three causes combined. Stain is listed as loss due to air drying even though most degrade of this type was measured in surfaced kiln-dried lumber rather than in rough air-dried lumber because stain was not readily apparent in the rough lumber. This lumber was already too dry for stain to develop when the lumber was ready for the kiln.

The types of degrade usually attributed to kiln drying (end splits, checks, warp, etc.) caused additional degrade during kiln drying. But the additional degrade due to kiln drying totaled only 4.6 percent (table 4).

Much of the degrade observed in the lumber cannot be attributed to the drying (table 5). Beetle damage caused degrade in 6.3 percent of the lumber. This damage, confined to the sapwood, had started in the logs before sawing and continued during air drying. Control can be effected by chemical spray on the logs and chemical dip of the freshly sawed lumber. Certain natural defects not noticeable in the rough air-dried lumber but clearly visible in the surfaced lumber were responsible for the greatest change of grade (21.4 percent). Machining caused degrade amounting to 3.7 percent, and errors in grading (an upgrading) accounted for 2.5 percent.

A total of 55.4 percent of the study lumber changed one or more grades from green to surfaced dry: 2.5 percent increased one or more grades and 52.9 percent was lowered one or more grades. Of the net change, degrade directly attributable to drying (air drying and kiln drying) amounted to 21.5 percent. The remainder (31.4 percent) was due to other causes, primarily pin knots and other natural blemishes.

CONCLUSIONS AND RECOMMENDATIONS

The 5-foot spacing of the yard piles promoted more rapid drying and drying to a lower moisture content than did the 1-foot spacing. The effect of the pile protection on the rate and extent of drying was less distinct.

End splitting and surface checking of lumber are usually associated with rapid drying under severe conditions of low humidity, usually accompanied by high temperatures. Stain, on the other hand, is usually associated with slow air drying under conditions of high humidity and precipitation. In this air-drying experiment both types of degrade developed in all study piles. Apparently, drying conditions resulting from the weather had a more pronounced effect on drying than could be adequately overcome by the variation in piling methods included in the experiment.

The monthly variation in drying conditions in Hilo appears to be similar to the seasonal change of drying conditions in timbered areas of the mainland. Therefore the most severe weather conditions that can be expected during the drying period should be considered in determining the proper degree of openness of the yard, and the amount of precipitation should be considered in judging the degree of pile protection.

Methods of reducing the end checking and splitting should be examined. Possibilities include close end spacing of piles or end coating with a moisture sealant to reduce end drying. A careful evaluation of different types of roofing or complete protection in drying sheds and the use of chemical dips may reveal better methods of preventing blue stain.

Although the height of pile foundations was not studied as a variable in this experiment, good foundations were provided. Their $15\frac{1}{2}$-inch height permitted free air movement under the piles. This height was a distinct improvement over the usual procedure of placing piles of 4- x 4-inch bolsters. That this foundation can be further improved is indicated by the consistently higher moisture content of lumber in the bottom four courses of each pile. Yard paving may be warranted.

Table 3.--Grade change due to air drying (green to air dried)

Cause of grade change	Spacing and protection on the yard						
	One-foot spacing			Five-foot spacing			Total
	Open	Roofed	Both	Open	Roofed	Both	
End checks and splits							
Number of pieces	6.0	9.0	15.0	[1] 5.5	3.5	9.0	24.0
Board feet	38.5	51.6	90.1	32.0	18.6	50.6	140.7
Percent of total, bd. ft.	5.4	7.5	6.4	4.7	2.9	3.4	5.1
Surface checks							
Number of pieces	4.0	5.0	9.0	1.5	2.5	4.0	13.0
Board feet	25.4	26.7	52.1	7.9	13.3	21.2	73.3
Percent of total, bd. ft.	3.5	3.9	3.7	1.2	2.0	1.6	2.7
Warp							
Number of pieces	--	--	--	--	1.0	1.0	1.0
Board feet	--	--	--	--	6.7	6.7	6.7
Percent of total, bd. ft.	--	--	--	--	1.0	.5	.2
Stain							
Number of pieces	12.0	9.0	21.0	14.0	8.0	22.0	43.0
Board feet	77.9	51.2	128.7	67.5	49.4	116.9	245.6
Percent of total, bd. ft.	10.8	7.4	9.2	9.9	7.6	8.8	8.9
Totals							
Number of pieces	22.0	23.0	45.0	21.0	15.0	36.0	81.0
Board feet	141.8	129.5	270.9	107.4	88.0	195.4	466.3
Percent of total, bd. ft.	19.7	18.8	19.3	15.8	13.5	14.3	16.9
Total board feet in sample	706.0	709.6	1,415.6	713.0	714.4	1,427.4	2,843.0

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[1] Degrade of some pieces was due to two causes, thus in some cases fractions of pieces are shown.

Table 4.--Grade change due to kiln drying (rough air dried to surfaced kiln dried)

Cause of grade change	Spacing and protection when on the air yard						Total
	One-foot spacing			Five-foot spacing			
	Open	Roofed	Both	Open	Roofed	Both	
End checks and splits							
Number of pieces	2.0	3.0	5.0	1.0	1.0	2.0	7.0
Board feet	11.2	15.6	26.8	8.0	8.0	16.0	42.8
Percent of total, bd. ft.	1.6	2.3	1.9	1.1	1.2	1.2	1.6
Surface checks							
Number of pieces	4.0	6.0	10.0	[1] 2.5	3.0	5.5	15.5
Board feet	24.8	27.9	52.7	13.3	12.6	25.9	78.6
Percent of total, bd. ft.	3.5	4.1	3.8	2.0	1.9	1.9	2.9
Warp							
Number of pieces	.5	--	.5	--	--	--	.5
Board feet	2.6	--	2.6	--	--	--	2.6
Percent of total, bd. ft.	.4	--	.2	--	--	--	.1
Total							
Number of pieces	6.5	9.0	15.5	3.5	4.0	7.5	23.0
Board feet	38.6	43.5	82.1	21.3	20.6	41.9	124.0
Percent of total, bd. ft.	5.5	6.4	5.9	3.1	3.1	3.1	4.6
Total board feet in sample	706.0	709.6	1,415.6	713.0	714.4	1,427.4	2,843.0

[1] Degrade of some pieces was due to two causes, thus in some cases fractions of pieces are shown.

Table 5.--Degrade not related to drying[1]

Cause of grade change	Spacing and protection on the yard						
	One-foot spacing			Five-foot spacing			Total
	Open	Roofed	Both	Open	Roofed	Both	
Beetle holes							
Number of pieces	12.5	3.0	[2] 15.5	7.5	8.0	15.5	31.0
Board feet	73.1	17.3	90.4	36.6	45.8	83.4	173.8
Percent of total, bd. ft.	10.2	2.6	6.5	5.5	7.1	6.3	6.3
Natural defects							
Number of pieces	19.5	40.5	60.0	19.0	23.0	42.0	102.0
Board feet	123.2	222.2	345.4	113.2	127.8	141.0	586.4
Percent of total, bd. ft.	17.2	32.3	24.6	16.6	19.6	18.1	21.4
Machining							
Number of pieces	2.5	2.5	5.0	10.0	4.0	14.0	19.0
Board feet	13.9	13.8	27.7	53.4	19.9	73.3	101.0
Percent of total, bd. ft.	1.9	2.0	2.0	7.8	3.1	5.5	3.7
Grader (grade raised)							
Number of pieces	2.0	2.0	4.0	3.0	6.0	9.0	13.0
Board feet	13.3	8.0	21.3	15.3	30.6	45.9	67.2
Percent of total, bd. ft.	1.9	1.2	1.5	2.2	4.7	3.4	2.5
Totals							
Number of pieces	36.5	48.0	84.5	39.5	41.0	80.5	165.0
Board feet	223.5	261.3	484.8	218.5	224.1	343.6	928.4
Percent of total, bd. ft.	31.2	38.1	34.6	32.1	34.5	33.3	33.9
Total board feet in sample	706.0	709.6	1,415.6	713.0	714.4	1,427.4	2,843.0

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[1] Combined figures for degrade measured after air drying and kiln drying.

[2] Degrade of some pieces was due to two causes, thus in some cases fractions of pieces are shown.

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1962. Drying of silk-oak in Hawaii. U. S. Forest Serv. Pacific Southwest Forest and Range Expt. Sta. Tech. Paper 65. 11 pp.

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